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ABSTRACT

This paper explores a teacher's perspective of what successful science instruction is and how these perspectives influence classroom instruction. The data sources for this study include 35 classroom observations and approximately 25 hours of interviews collected over a period of 2 years of a single high school chemistry teacher. During class, extensive field notes were written and for approximately half of these sessions, the teacher was interviewed for about 30 minutes following the lesson. The interviews after class focused on questions of what the purpose of the lesson was, whether it was a success, and how he decided if it was a success. Questions about why specific instructional tasks or chemistry content had been chosen were also asked. This teacher was also interviewed regarding students' written work, which consisted of tests, lab reports, journals, and a variety of other forms of written work, and how these provided evidence for his assessments of his own instruction. Analysis of the data involved reading the verbatim transcripts of the interviews and the field notes to develop a system of categories that were elaborated and modified with new data. In reflecting back on the successes and failures of several weeks or even an entire year's worth of instruction, the teacher assessed his teaching by referring to whether students had met a large array of goals that were affective, social, cognitive, and skill-based. The ways in which the teacher defines success for his students is then related to what researchers define as success. (KR)

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What counts as success? Perspectives from practice and research

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What counts as success? The question has been the source of much debate. At the level of policy, science education researchers have typically been very critical of current policies that measure success by scores on standardized tests (Lovitts & Champagne, 1990). At the level of practice, science education researchers have been critical of teachers who measure success by task completion (Gallagher & Tobin, 1987; Roth, 1989). However, even within the research community there is no uniform way in which "success" is defined.

This paper will explore a teacher's perspectives of what successful science instruction is and how these perspectives influence his classroom instruction. Then I will discuss the perspectives of the research community on what they count as a success. Finally, I will draw some conclusions about the tensions that exist between the two communities. The findings here are not intended to be definitive, but to generate discussion about an often neglected issue.

Perspectives from practice

Past research on teaching has tended to focus either on evaluating teaching based on what we believe research on learning says teachers ought to do, or it has focused on changing teachers so that their thinking and actions are more in line with what we believe research suggests they ought to think about and do. This research is most often undertaken from an *etic* perspective, in which the researcher describes the classroom from her/his point of view.

While much of this work has been useful and interesting, the rhetoric of the new reforms (Carnegie Forum, 1986) states that teachers should no longer be considered simply implementers of reform, but leaders in shaping the reform (McDonald, 1988). For this reason it may also be useful to consider if there are other important aspects of teaching that could be brought to light if we were to try to understand teaching from the insiders' perspectives, an emic perspective, and examine how teachers make sense of their work. In other words, in listening carefully to how teachers talk about their work, we may be able to better understand the professional practice and the sense-making processes that teachers use to cope in their work. This is not to say that it is not possible to judge bad teaching and good teaching, but making such distinctions will not be my intention here. Instead, I am interested in teachers' judgements of their teaching. As Baird (1988) has suggested:

> Given that teaching is done by individuals, with their own unique collections of thoughts, beliefs, aspirations, values, concerns, perceptions and abilities, it is surprising that so little research has been directed to what teaching means to individual teachers and how they describe how they go about it (p. 59).

Classrooms are often considered to be places where students learn. However, classrooms are also places where teachers learn by constructing useful knowledge to accomplish pragmatic goals (Shapiro & Roberts, 1989; Tobin, Briscoe & Holman, 1990). Furthermore, this sense-making process is influenced by teachers' interpretations of events that occur in the classroom. In this

respect teachers' thoughts, beliefs, etc.. must be thought of as not only influencing practice but also as being shaped by their practice.

Assessment is an ongoing event in the classroom. Teachers are constantly making judgments about what students are doing and learning to guide decisions about instructional time and strategies. This kind of interactive decision-making has been the subject of considerable study by researchers (Clark & Peterson, 1986). This research is most typically carried out by researchers conducting stimulated recall interviews following lessons which have led to models of teacher interactive decision making in which teachers conduct a lesson, pick up cues as to whether this "is working," and then, if their repertoire consists of alternative strategies, they make decisions about other courses of action.

While this research has been important, it is also limited because teacher behaviors are studied in the absence of any meaningful contexts. This leads to generic descriptions of teaching that are useful in their generalizability, but limited in their ability to capture the peculiarities, contradictions, and tensions inherent in classroom life. Furthermore, teacher assessments do not consist only of isolated, on-the-spot judgments, but also of long-term analyses of what has worked well through the years. This study will examine these analyses of instruction from a teacher's point of view.

Methodology

The data sources for this study include 35 classroom observations and approximately 25 hours of interviews collected over a period of two years of a single teacher, David. [A pseudonym is being used pending permission from his school district to use his real name.] During class, extensive field notes were written and for approximately half of these sessions, the teacher was interviewed for about thirty minutes following the lesson. The interviews after class focused on questions of what the purpose of the lesson was, whether it was a success, and how he decided if it was a success. David was also queried about specific instructional tasks or chemistry content he had chosen to teach. In addition to these interviews, David was interviewed regarding students' written work, which consisted of tests, lab reports, journals, and a variety of other forms of written work, and how these provided evidence for his assessments of his own instruction. Finally, David was interviewed in more casual settings concerning the general progress of his students. All interviews were audio-recorded.

Analysis of the data involved reading the verbatim transcripts of the interviews and the field notes to develop a system of categories that were elaborated and modified with new data. Contradictory evidence for emerging hypotheses were sought in order to expand or restrict the categories (Goetz & LeCompte, 1984).

The Case of David

David has been teaching chemistry for over 26 years. His honors chemistry students have been finalists in state-wide competitions and he has won state-wide awards for excellence in chemistry teaching. Finally, he has been recognized on two occasions by the valedictorian as being the teacher who most influenced her. David teaches two chemistry classes: (1) a college preparatory course that uses the ChemCom textbook, developed by the American Chemical Society and focusing on the relationship between chemistry and society, and (2) an honors chemistry course, for the "best" of the college preparatory students who will not only be going to college, but will likely be taking college chemistry courses and may major in a science-related field. This course uses the textbook, Chemistry by Masterson, Slowinsky & Wolford and includes content that is similar to what the students will encounter in college.

The question of what counts as success cannot be answered unless one has a vision of what it is one is trying to achieve. Therefore interviews following instruction elicited a great deal of discussion concerning David's goals for his students. What is perhaps most interesting about these goal statements is their diversity. David's purposes for teaching chemistry encompassed a wide array of learning intentions for his students that included content goals such as understanding chemical concepts, making connections between school chemistry knowledge and the larger natural and social world, using chemical language, and solving

numerical chemistry problems. In addition to content goals, David was also concerned that students develop mathematical and laboratory skills such as using metric units, using significant figures, using scientific notation, using charts and diagrams, manipulating numbers in formulas, using laboratory equipment, and learning laboratory techniques. David was also concerned about developing students into responsible adults who can think critically and be productive members of society. To address these goals, he assigned tasks that required them to read and write critically and to analyze data critically. Furthermore, he also used journals to build positive relationships between himself and his students and used group work to develop relationships between students.

David summarized how he assessed "where the course was":

> talking to kids, looking at tests, [if they are] turning in homework, quality of lab work, how willing [they are] to do extra credit.

David's interactions with his students gave him information about both their attitudes toward him and about the course as well as what they were learning in the course. Student willingness to complete extra credit work was interpreted as a sign of motivation. Tests were a measure of what they were learning and he liked using some of the same tests year after year so he could compare classes to one another. Their lab work gave him information about the quality of their lab skills and reports were used to assess their ability to make sense of data collected. Finally, turning in homework told David if the

students were acting responsibly toward their academic work. These criteria for success will be discussed more thoroughly in four rather broad and overlapping categories of motivation, learning, skill development, and socialization.

Are the students motivated to learn?

Although students liking chemistry and being highly motivated was never mentioned as a specific goal of instruction, it was nevertheless, the most important means by which he decided whether instruction was working. This was especially true when David was assessing his teaching immediately after class. David believed this was critical because you cannot force a kid to learn anything if s/he does not want to learn. David explained this position as follows:

> I don't care how good the teacher is, if the kid sits there and says you're not going to teach me anything, ok? I defy you to do it.

David assessed student motivation in a variety of different ways, including completing assignments, asking thoughtful questions, and doing extra credit work.

In judging the effectiveness of a field trip that involved students gathering chemical data on a local stream, David said:

> Pretty much it happened the way I expected it. I think I was surprised in a positive way by how eager the kids were to it. I really felt that we would have some kids reluctant to go out to the stream -- out to the site thinking it was a waste of time. I was surprised by how effective the planning was as far as the organization and how the kids responded to that organization ... probably on a negative way is the lack of some of the students to really buy into it. I had one boy who when we were out there spent 10 minutes and went up and sat on the bus the rest of the day.

Motivation in laboratory activities was assessed by student attitude toward the work.

> They went back and they approached the laboratory with a degree of seriousness that I liked ... They followed my directions without too much question or without any, no, I don't want to do that or that's dumb.

This excerpt should not be interpreted that David believed that questions should not be asked. His assessment depended on the nature of the question. If the question was procedural or about something he thought they ought to know, then he assumed they were inadequately prepared. If however, the questions were related to things they had not directly talked about or read about, then they were an indication of high motivation, curiosity, or conscientiousness. David made this distinction as follows:

> I have other kids who have asked me about water and fishing when we were doing the water unit because he knows of a very stagnant pond that's being treated that's being outlawed for swimming or something where he lives. Honors kids - their question is "is this on the test?"

Although typically David integrated the content being covered with laboratory activities, that was not always the case. Motivation was so important, that David would use laboratory activities that were not related to the content currently being covered in the course because they were fun and gave the students a break from more tedious work.

> If I stood up here and talked about the atom for another day, numbers and so on, they really turn off. So it gives them a break from doing all that. It allows them to handle some equipment and chemicals that they'll run into later.

Are the kids learning anything?

Whether the students were learning what David intended them to learn was assessed on a daily basis during classroom discussions and during lab sessions both by students' questions to David and to their responses to his questions. On a longer time scale it was assessed with tests and other written work.

Classroom discussions were an important tool in helping David decide whether the students were learning the ideas he was trying to teach.

> I think they understand properties because of some of their interactions with me, the fact that they were identifying properties.
>
> They knew it. They told me how to diagram an exothermic reaction on the board, and endothermic - where the reactants and products would be placed in relation to one another, where the sign convention would be. It's a feeling you get. You know when it's there.

Similarly, David was disappointed with the reaction to a discrepant event because only a few students seemed to be surprised by it.

> ...the fact that they did not respond, whenever Carrie gave the explanation. There was reaction really from three or four people. I would have expected them to ooh, ah, or that's not fair, or tricky.

It was important that David see that the students were "with him," i. e. that they could keep up with the conversation he was attempting to engage them in. Furthermore, this conversation must include more than just a few bright students.

Student learning in laboratory activities was judged by student activity and by the products students were able to

produce from them. David frequently moved through the laboratory asking students questions about what they were doing and why they were doing it to determine if they had prepared for lab and if they understood the purposes and procedures.

> I know it was successful by the results that the students got, the smoothness with which they were able to move through the laboratory with a minimum of real problems or questions concerning procedures. They really seemed to understand what they were doing and why they were doing it.

David's view of a successful lab was one in which the students could work through the lab with a minimal of difficulty or frustration.

In daily lessons, David judged the effectiveness largely by what students were able to do, whether it be keep up with the dialogue in class or complete a laboratory activity with the expected results.

Longer term assessments of what the students learned were made with a variety of written assignments. These included tests, laboratory reports, newspaper article analyses, and other miscellaneous assignments.

Tests were given primarily for the purpose of accountability. They tell David if the students have been working hard and if they are learning how to solve problems and understanding chemical concepts. David's tests for his honors students were frequently long tests that required students to exhibit skills that should have been largely automated. His tests for his college preparatory class were more likely to require students to write paragraphs about science concepts and

to ask them to apply their chemical understandings of everyday occurrences.

On laboratory reports David expected students to follow the format given, a very traditional laboratory report format, and that they perform necessary calculations. However, what distinguished a good report from a poor one was most determined by how students addressed the purpose of the lab. If the purpose of the lab was to show students the different characteristics of solutions, mixtures, and pure substances, then in reading laboratory reports, David was primarily concerned that the students' conclusions include their understandings of these characteristics. Laboratory activities served a large variety of purposes that ranged from understanding concepts to developing skills.

It was also important to David that his students be able to understand the chemistry of everyday occurrences and of their importance in social issues. For this reason, he required his college preparatory class to critique popular science articles or newspaper articles that were related to the ideas being discussed in class. He believed that this aspect of his course has worked reasonably well because students frequently spontaneously brought in questions to chemistry class that they had read or heard about that concerned them. Interestingly, this rarely occurred in the honors course. David does not think any of his students are able to <u>use</u> their knowledge of chemistry to understand these problems as well as he would like. However, he thinks they at least see

that chemistry can help them understand everyday events and social problems.

Past research has often revealed that some teachers are naive about what their students are learning. They often assume the students know far more than they actually do. This was not the case for David. He never jumped to conclusions about student learning based on task completion or his interactions with just a few students. The critical dilemma that David dealt with was what depth of understanding is sufficient and how many of his students should he expect to develop this level of understanding.

Are the students developing scientific skills?

As previously mentioned, David taught chemistry for college bound students and for honors students. He was very committed to preparing his honors students for college chemistry. Although many of his commitments to traditional chemistry teaching changed for his college preparatory classes with his adoption of the ChemCom text, he was still very concerned that these kids will go to college, and although they may not major in a scientific field, they may be required to take a college chemistry laboratory course. For this reason, he included material that is primarily concerned with skill development for use in college courses. These consisted of a variety of laboratory skills and "number handling." During the first few weeks of school several of his lessons in both classes were primarily focused on skill development (how to use the balances, using scientific notation and significant digits). After the first few weeks however,

students learned new skills only as they were needed. However, skill development was still an important criteria for selection of labs and for judgements regarding the success of a lab throughout the year.

David constantly monitored labs. When he walked around the room during a laboratory activity, one of the things he looked for was that students could use the equipment, record data appropriately, and that they understood what they were doing.

> I think that it went very well, better than it did on Monday. They seemed to have a better sense of what they were doing ... They seemed to have more interest and direction.

When asked what he looked for to make this determination, David responded:

> Probably because of the way they recorded their numbers here. Also because they were on-task almost exclusively ... they were utilizing the balances. They were working with the hot plates. They were asking me questions about should I have it up this high on the hot plate?

Activity of this sort informed David that the students prepared for the lab (evidence of motivation and responsibility goals being met) and that earlier efforts made in learning to use the equipment and correctly report significant digits had been mostly achieved.

In addition to these skills, David also wanted his students to be able solve routine chemistry exercises with dimensional analysis. Once again, this was related to his concern for preparing these students for future coursework. (Interestingly, he was also well aware of the problems associated with this

approach, i. e. that students can be trained to work problems using this method, yet not understand the concepts. However, he also believed that being able to get the right answer will be important to them in succeeding on exams not only in his class, but also in college.)

> I don't know whether it's the way we should be teaching it or not because it's sort of a false method... I can solve all types of chemistry problems without understanding the chemistry at all ... It is something the kids have to be able to do. They have to be able to solve these problems. I've found over the years solving problems in this course generally leads along to understanding the chemistry. But whether it's because they're just understanding the chemistry or they're understanding it through their problems, I don't know. I've found that the kids in the second year course really start looking at chemistry problems as chemistry problems and not as exercises to be solved with dimensional analysis. But that takes a more sophisticated look at the chemistry.

The one lesson that David judged to be the biggest failure was when he introduced dimensional analysis. He had a very difficult time convincing the students that they should use this method, especially if they thought they could solve the problem in their head. Their comments in class indicated that they believed this to be an inefficient use of time, particularly on tests when their time was limited. David responded by giving them a problem they could not solve in their heads. This still failed to convince them that they should use it for all problems.

> It got to the point with dimensional analysis, problem solving, I couldn't justify it to them by them needing it...hopefully they will see later.

In this situation, the students were not convinced that learning this method was in their best interest. This created tension

between David and his students which was never clearly resolved. David defined the problem so that he would not have to make a choice that required either he or the students lose. Problems appeared on the test that could be solved with dimensional analysis, but students could use any method to solve the problem. However, as David continued to model using dimensional analysis throughout the year, he found students gradually adopted it. He also believes that some of his students are now beginning to understand the relationship involved in these problems.

Are the students developing socially?

In early interviews eliciting David's goals for his students and in interviews following class in which I asked him for justification for particular decisions, I found that David's goals included far more than just cognitive goals. They also included social goals of responsibility and cooperation. David wanted his students to develop good work habits and an ability to work with other people.

David was also particularly concerned with how the students were working together - another aspect of ins ruction that he made judgments about very quickly based on readily observable criteria.

> They worked well within their grouping. They used the techniques I had up here. They were very quiet about it. They were asking each other questions about it. They were staying with their group and not crossing groups.

Although David assessed immediately whether the group work was meeting his instructional goals and his socialization goals

within the classroom, his purposes for including cooperative learning extended beyond the classroom. They were more related to his social goals than to cognitive ones (although he hopes they are achieving cognitive goals as well). He believes that to thrive in today's workplace, learning to work with other people on related tasks is absolutely essential.

In addition to this he wants them to take responsibility for their own learning and to develop a work ethic. To do this he gave them independent assignments and homework. Homework was only checked for completion and was not accepted late. David frequently made judgments about the work ethic of his students based on whether they took responsibility to do their homework and learn the material for exams.

Many of David's cognitive and skill-based goals are actually also social. The reason why David believes that successful instruction includes students learning traditional chemistry content, working traditional textbook chemistry problems and developing laboratory skills is that this socializes them for college chemistry courses.

Summary

Some of David's methods for judging the success of his own teaching could have probably been predicted from past research. In particular, the amount of attention given to engagement and task completion would be expected based on the research of Gallagher and Tobin (1987) and Sanford (1987). However, David judged his teaching on other criteria as well, such as interest,

questions and participation in discussions, cooperation, numerical and laboratory skill development, and results from laboratory reports, tests, and other written work. In reflecting back on the successes and failures of several weeks or even an entire year's worth of instruction, David assessed his teaching by referring to whether students had met a large array of goals that were affective, social, cognitive, and skill-based.

Perspectives from research

In the same sense that attempts to describe a uniform culture of schools is likely to distort the complexity of schools and important differences between schools or between teachers, the same limitations would be applicable to attempts to describe a uniform culture of science education research. There is no uniform way in which research defines what counts as an instructional success. In examining instructional studies in science education research journals, I find that successful instruction is measured by many criteria. Getting the "right" answers on objective content tests is the most frequently used criterion for success. Also used are concept maps, course or exam grades, process skills tests, tests of reasoning abilities, and attitudes.

What is most interesting about this is that rarely is success defined by more than a single criterion. Furthermore, what counts as success is largely determined by the theoretical orientation of the researcher. For example, conceptual change researchers measure success by the replacement of misconceptions

with the scientific canon (e g. Anderson, Sheldon, & Dubay, 1990), inquiry researchers measure success by the development of process skills or thinking skills, STS researchers measure success by students' ability to apply knowledge and make decisions (Yager & Hofstein, 1986). Researchers tend to target very specific goals and then orient the instruction and the assessment of the instruction toward those goals. Most often the purpose of the research is to compare an instructional method or materials to another method or materials in order to effectively argue that one method is better than the other. However, the arguments become rather circular. For example, evaluation of inquiry learning rarely attempts to find out if misconceptions are being replaced by the scientific canon and evaluation of conceptual change rarely attempts to find out if the students are developing process skills or critical thinking skills. In essence, how a researcher evaluates tells us what they believe the most important purposes of science education are. If we look at David's teaching, we see a similar relationship. He also judges success by what he believes the purposes of teaching high school chemistry are. However, his purposes are far more diverse than would ever be tackled by researchers focusing on a single criterion of success.

David does not fit cleanly into any of the previously mentioned categories and also exhibits traits of a traditional didactic high school chemistry teacher concerned with preparing his students for future chemistry courses. His practice

indicates he is trying to meet the goals of preparation for future chemistry courses as well as for preparation of citizens. Interestingly, data from interviews alone would have led me to expect that there would be little emphasis on preparation for college chemistry. However, observing classes led me to question specific aspects of his instruction. The result of the interviews that followed was that I learned that David felt conflicts about his responsibilities in educating these students. Furthermore, his past practice has been more oriented toward preparation for college and he has received considerable encouragement for this, including state-wide teaching awards and thank you letters from university professors for his success in preparing students for college chemistry. When David adopted the ChemCom textbook, he basically added the purposes of STS educators to his already diverse agenda.

This highlights the essential problem that science education researchers are trying to solve very different problems than practitioners. Researchers want very much to know what instructional methods or materials are better than others and why. Teachers are also solving problems and the problems they identify in their environments shape the knowledge they construct. The problems David attempts to solve are far more diverse and particularistic than are typically held by researchers. He wants to figure out ways of challenging his students while maintaining high student engagement. Furthermore, whereas researchers concern themselves primarily with academic

learning, David is interested in far more than that. He is also interested in educating students who understand the value of hard work, who can work with other people, who have the skills to pass a college chemistry course (where these skills are likely to be useful), and who can read a newspaper article involving chemistry and be able to make sense out of it.

Working with Teachers and Building a Community

The gap between educational theory and the science classroom has almost become a cliché used to describe the problems in science education practice. Such statements often assume that there is consensus on which theory we are talking about. There is no gap in teachers' theories of teaching and their classroom practice. Perhaps the problem is with the gap between researchers' theories of learning and classroom practice. Teachers fail because they do not know our theories of learning well enough to know how to implement them in their teaching. However, while that may be a partial answer it is also too simple an answer because it assumes that theories of learning can be directly applied to teaching and fails to address the complexity of classroom culture. What I would like to suggest is that the gap that exists between how researchers define success and how a teacher such as David may define success points to fundamental differences in what they are trying to accomplish.

Researchers tend to act as if educational purposes were a given (Zumwalt, 1989) and many seem to assume that they are synonymous with high scores on various pen and paper tests. This

is a rather myopic view of the purpose of science education and may partially explain why attempts to "translate research into practice" so frequently fail. We've tried to change practice prior to understanding practice from the teachers' points of view. Furthermore, the responsibility for implementing change tends to rest on the researcher rather than the teachers (Dobbert, 1982).

Most often, efforts to change teaching practice have concentrated on changing teachers' attitudes or competencies or on providing teachers with additional strategies or materials in order for them to meet what researchers believe are the most important purposes of science education. The purposes are rarely the subject of debate. Sometimes such efforts meet with some success, although frequently they fail, and long-term implementation, when assessed, is almost always judged a failure.

I would like to speculate that this is likely to continue so long as we focus on giving teachers materials and strategies rather than developing teachers with principled knowledge for decision-making. To meet the challenge of the new reforms and build a community of researchers and professional teachers it is critical that we engage teachers in the philosophical debates about the purposes of science education in ways that are grounded in the problems of practice. Furthermore, reform efforts must take into account teachers' goals and judgments of "success." If researchers or policy makers do not engage in genuine dialogue with teachers over what ought to count as success, then we can

expect that they may define it in different ways. The result is to perpetuate the separate cultures of teachers, researchers, and policy makers.

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